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ACQUIRING AUTOMATICITY OF BASIC MATH FACTS AND
THE EFFECT THAT THIS HAS ON OVERALL
MATHEMATIC ACHIEVEMENT

by

Sandra S. Robinson

A Thesis

Submitted in partial fulfillment of the requirements of the
Master of Arts Degree
of
The Graduate School
at
Rowan University
Spring 1999

Approved by _____

Date Approved April 26, 1999

Abstract

Sandra S. Robinson
Acquiring Automaticity of Basic Math Facts and the Effect that this has on Overall
Mathematic Achievement
1999
Dr. Stanley Urban

The purpose of this study was to prove, through a systematic approach, that teaching addition facts to mastery would improve the mathematics scores of second grade students. This study attempted to demonstrate that if a desired level of automatic recall of basic facts was achieved students would show improved scores on a nationally standardized test.

Basic math facts were taught to a group of students over several months and they were tested daily on speed and accuracy . Standardized test scores were then compared from the end of first grade (prior to the intervention) and end of second grade scores (after the intervention) for each child who participated in the experimental group. This group was then compared to a group that had no intervention to see if there was a significant level of improvement, as measure by their end of first grade and end of second grade standardized test scores.

The findings to the research question was that there were no differences, statistically, in the pretest calculation abilities of the control or experimental groups, and there were no differences, statistically, in the posttest calculation abilities of the control or experimental groups. However, it can be concluded that individual students made significant gains with the extensive drill and practice. Further research with a larger group of subjects may lead to more significantly favorable findings.

Mini Abstract

Sandra S. Robinson

Acquiring Automaticity of Basic Math Facts and the Effect that this has on Overall
Mathematic Achievement

1999

Dr. Stanley Urban

The purpose of this study was to prove that teaching addition facts to mastery would improve the mathematics scores of second grade students. This study attempted to demonstrate that if a desired level of automatic recall of basic facts was achieved students would show improved scores on a nationally standardized test. The findings were not significant. However, it can be concluded that individual students made significant gains. Further research with a larger group of subjects may lead to more significantly favorable findings.

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CHAPTER I STATEMENT OF THE PROBLEM

INTRODUCTION:

Walk into any elementary classroom during mathematics instruction and one will most likely observe students calculating simple math facts on their fingers. In a first grade classroom this would be expected behavior, however in a fifth grade classroom it is a disconcerting sight. Why are fifth grade students reliant on their fingers to compute $7 + 5$?

Proponents of the new mathematics curricula would, perhaps, argue that we need to stress higher level mathematics skills and not spend a great deal of time on the memorization of math facts. These newer approaches fill their curricula with thinking skills exercises, but offer very few activities to promote the memorization of math facts. Teaching math facts has essentially gone the way of teaching phonics. The proverbial educational pendulum has swung away from direct instruction activities toward a more strategy based, whole concept, application style of teaching. This “discovery method of teaching” philosophy strongly objects to rote practice or memorization. In fact critics refer to this method of instruction as “drill and kill.”

The purpose of this study is not to suggest that all teaching should be direct instruction. A balanced approach to teaching is likely the most appropriate and effective method of educating our students. However some things are learned better and are more valuable when committed to memory. Math facts should be memorized to the point

where a level of automaticity is achieved. If students have automatic recall of math facts they, theoretically, will be more efficient in higher level mathematics computations.

After years of teaching and tutoring students in mathematics I have noticed two alarming trends. The first trend is that many upper elementary students do not know their math facts to the point of automaticity. They can figure out the answer to “ $13-5=$ ” but they do not have the fact committed to memory. While most students develop adequate compensation skills (such as using their fingers), most of these compensation skills require more time and an extended thought process. According to Pellegrino & Goldman (1987) it is important for students to perform lower-level cognitive skills (like computing math facts) proficiently, automatically, and accurately so that they can acquire higher-level cognitive math skills. The second trend is that the majority of errors in higher level skills, such as long division, are errors in basic math facts. The astonishing thing I have observed is that when students break the process of computing a long division problem to subtract “ $13-5=$ ” they often confuse the long division process. If the fact were recalled automatically, the long division process would not have been interrupted. Because school mathematics routinely builds on basic skills, it is important that a child use such skills accurately and automatically. Automatic subskills reduce the load on working memory and free attention to focus on more complex tasks. (eg., Hasselbring et al., 1987; Resnick & Ford, 1981).

NEED FOR THIS STUDY:

The scope and sequence charts for teaching mathematics generally begin math facts in two operations-addition and subtraction-very early in the first grade year. Many

students have difficulty mastering these basic facts or they are not taught memorization to a mastery level. Weaknesses in this foundational skill will, in turn, cause continued difficulty in mastering the higher level math skills.

The sequence in which skills are presented determines in part the amount of difficulties students will have in learning strategies. Also, preskills should be taught prior to the introduction of strategies that require their application. Many commercial programs do not teach all of the necessary preskills. A program should allow ample time for the student to master the preskills. Most commercial programs that do provide for the teaching of preskills, however, often fail to provide enough practice on the preskill before it is integrated into a strategy. (Silbert et al., 1990)

This study will provide useful data to elementary mathematics teacher to support that teaching preskills until mastered (specifically math facts) is not a waste of teaching time. Mathematics curriculum developers need to allow plenty of time for practice and reinforcement of basics math facts since they are the absolute foundation of most higher level math skills. Teachers need to be innovative enough to make this a priority in their daily lesson plans even if curriculum developers refuse to devote adequate time for these preskills. Taking more time in the early grades to master these skills should benefit students for years to come.

VALUE OF THE STUDY:

This present study is prompted by an increase concern regarding the number of upper elementary grade students who have not mastered the skill of memorizing the 390 basic math facts. Educational, business and government leaders now recognize that it is

essential to foster strong mathematical capabilities in our students. *A Nation at Risk*, written by the National Commission on Excellence in Education (1983), stated two key reasons for improving our student's mathematical abilities. The first is that our increasingly information and technology-based society require different mathematical competencies than those required by the industrial society of just twenty-five years ago. With the widespread use of computers and calculators it is more important now to know how "to organize, manipulate, and interpret quantitative information" than it is to master basic arithmetic skills (Fey, 1990, p. 65)

The second reason our society must push forward in improving our overall mathematics education programs in our schools is that mathematical power is essential for surviving intense international competition. World wide research consistently places the mathematical achievement of United States school relatively low when compared to other industrialized nations. (eg., McKnight, C.C., Crosswhite, F.J., Dossey, J.A., Kifer, E., Swafford, J.O., Travers, K.J., & Cooney, T.J., 1987).

This study is an attempt to explore, experiment with, and document instructional practices that will help improve these eroding math scores. It will generate sound instructional objectives that are linked to theory and practice. It will attempt to address issues in mathematics that reflect problems educators now face in attempting to change their perspectives on long held beliefs.

RESEARCH QUESTION:

Will second grade students who receive direct instruction, drill and practice of basic addition facts make greater gains on the California Achievement Tests than a control group that has had no intervention?

In order to answer the research question the following hypotheses will be tested:

H₁ -There is no difference in basic calculation skills between the experimental group and the control group used in this study.

In order to insure that the experimental and control groups are equivalent a pretest will be administered.

H₂ - Second grade children who receive four months of Direct Instruction in basic math facts will make greater gains in computational skills than a comparable group of second graders that do not receive the Direct Instruction method.

PURPOSE OF THIS STUDY:

The purpose of this study is to prove, through a systematic approach, that teaching addition facts to mastery will improve the mathematics scores of second grade students. This study will attempt to demonstrate that if a desired level of automatic recall of basic fact is achieved students will show improved scores on a nationally standardized test. Systematically teaching basic math facts to a group of students over several months and testing them daily on speed and accuracy should for most students bring them to a higher

level of automaticity. We would then compare standardized test scores from the end of first grade (prior to the intervention) and end of second grade scores (after the intervention) for each child who participated in the experimental group. This group would then be compared to a group that had no intervention to see if there was a significant level of improvement, as measure by their end of first grade and end of second grade standardized test scores.

DEFINITION OF TERMS:

Automaticity: is the ability to recall automatically certain rote-memory facts such as math facts. Automaticity is demonstrated by the ability to recall math facts within two seconds of the visual or auditory presentation of the fact. (Bender, W.N., 1998).

Basic Facts: There are 390 basic facts: 100 addition, 100 subtraction, 100 multiplication, and ninety division. Basic addition facts include all possible combinations in which each addend is a whole number less than ten. Basic subtraction facts include all possible combinations in which the subtrahend and the difference (a and b in $c-a=b$) are one digit numbers. Basic multiplication facts include all possible combinations in which each of the factors is a single digit number (e.g., in $a \times b=c$, a and b are single digits). Basic division facts include all possible combinations in which the divisor and the quotient are single digit numbers (e.g., in $c \div a=b$, a and b are single digit numbers, and a is not equal to zero). (Silbert, et al., 1990).

Direct Instruction: is a teacher-led instructional procedure that provides students with specific instructions on a task, modeling, signaling, practice and frequent feedback on their performance. Beck and colleagues (1982) found that average-ability students needed sixteen to twenty-two presentations of a new concept before they learned and remembered the skill. If an average student needs approximately twenty presentations to learn a new concept, it follows that students with learning disabilities may require additional opportunities to learn the skill. Commercially prepared materials are available that incorporated direct instruction philosophy. A classic example is DISTAR, the Direct Instruction System for Teaching Arithmetic and Reading . (Bender, 1993)

Sequencing Skills: The order in which skills are taught can affect the difficulty students have in learning them. Sequencing involves carefully determining the optimum order for introducing each skill and subsequent skills after that skill. According to (Silbert, J., et al., 1990) there are three guidelines for sequencing skills. These guidelines are (1) preskills of a strategy are taught before the strategy; (2) easy skills are taught before more difficult ones; and (3) strategies and information that are likely to be confused are not to be introduced either at the same time or consecutively.

Standardized Tests: are constructed by test specialists working with curriculum experts and teachers. They are standardized in that they have been administered and scored under standard and uniform testing conditions so that results from different classes and school may be compared. The objectives are general to the needs of most students in most classrooms. Items are fixed and are not modifiable. Only the most common areas of the

curriculum are tested. The rules for administration and scoring are determined by the test publisher. They must be followed exactly as prescribed in the manual for the test results to be valid. Data on validity and reliability are provided by the publisher.

LIMITATIONS OF THIS STUDY:

1. CONTROL GROUP SELECTION:

They arbitrarily divided the students who participated in this study into two groups. The two groups chosen were simply two second grade classes in an elementary school (The entire second grade population of the school.). Students were placed in one of the two classes based on academic ability, behavior, parental involvement, and several other factors that were at the principals discretion. This study will assume, for research purpose, that these are comparable groups. However, there is no way to be sure that the two groups are equivalent. In fact, the probability of the groups being equivalent is unlikely.

2. PRIOR ABILITY, OR CURRENT ACHIEVEMENT LEVELS OF STUDENTS IN STUDY:

Students bring to the learning environment a diverse amount of ability and experiential backgrounds. These students are each unique. No consideration is given for individual learning styles, prior experiential background or ability. All students in the experimental and the control groups were studied regardless of these factors. Students

range in ability from gifted and talented to classified for special services. There was not any student in this school's second grade population that was excluded from the study. The only students excluded were students that did not attend the school for first and second grade.

3. PARTICIPATING TEACHER'S TEACHING STYLES, INSTRUCTIONAL STRATEGIES AND TEACHER EXPECTATIONS:

The two groups in the study, as stated above, are two second grade classes. These two classes are taught by two very different teachers who bring to their classroom's their own philosophies of education. Each teacher has her own instructional strategies, teaching philosophies, and teaching styles. The teacher of the experimental group was very excited to participate in this study and spent a great deal of time working on fact memorization as a specific skill. The teacher of the control group was unaware that her students were even taking part of the study.

OVERVIEW:

Literature pertinent to this study is reviewed in Chapter Two. The theory of automaticity and the effectiveness of instructional techniques reflecting the importance of basic math facts memorization is the focus of the literature to be reviewed. The setting, population, instruments, and design of the study are described in Chapter Three. Analysis of results of the study are described in Chapter Four. Finally Chapter five will

be a discussion of the findings of this study, and the implication for future research needed in this area.

CHAPTER II REVIEW OF THE LITERATURE

INTRODUCTION:

This study provides an overview of the research on the necessity for the acquisition of automaticity when learning math facts. The research is divided into six sections.

- I. The need for improvement in overall education: A Nation at Risk
- II. Direct Instruction as a Learning Theory
- III. Project Follow Through
- IV. The need for automaticity of basic math facts
- V. The methods to achieve automaticity
- VI. Automaticity of basic math facts for students with learning problems.

THE NEED FOR AN IMPROVEMENT IN EDUCATION: A NATION AT RISK

On August 26, 1981 the Secretary of Education created the National Commission of Education and directed it to present a report on the quality of education in America. The report was titled, "*A Nation at Risk: The Imperative for Education Reform.*" This report made national and international headlines and was a loud wake-up call to all parents, education professionals, and policy makers at all levels of politics.

According to the report the Commission focused on several specific concerns. These included the following:

- assessing the quality of teaching and learning in our Nation's public and private schools, colleges, and universities;
- comparing American schools and colleges with those of other advanced nations;
- studying the relationship between college admission requirements and student achievement in high school;
- identifying educational programs which result in notable student success in college;
- assessing the degree to which major social and educational changes in the last quarter century have affected student achievement; and
- defining problems which must be faced and overcome if we are successfully to pursue the course of excellence in education.

The result of the eighteen month long investigation is that our Nation is, indeed, a “Nation at Risk”. The United States of America, since the industrial revolution, had dominated the world in commerce, industry, science, and technology. What this report found is that other countries are matching and surpassing our level of educational achievement. There were thirteen documented indicators of the “risk” reported by the commission in the published report including:

- International comparisons of student achievement completed a decade ago, reveal that on nineteen academic tests American students were never first or second and, in comparison with other industrialized nations were last seven times.

- Some 23 million American adults are functionally illiterate by the simplest tests of everyday reading, writing, and comprehension.

- Average achievement of high school students on most standardized tests is now lower than 26 years ago when Sputnik was launched.

- The College Board’s Scholastic Aptitude Tests (SAT) demonstrate a virtually unbroken decline from 1963 to 1980. Average verbal scores fell over 50 points and average mathematics scores dropped nearly 40 points.

- Between 1975 and 1980, remedial mathematics courses in public four-year colleges increased by 72 percent and now constitute one-quarter of all mathematics courses taught in those institutions.

The commission made recommendations for improvement in five major areas. The first area focused on the content of what we teach. The second recommendation

stated that our Nation's academic standards and expectation must be increased. The third area of improvement was dedicated to efficient time management and increased time-on-task.. The fourth recommendation dealt with improving teacher education, and mentoring programs for new teachers. The final area addressed the problems of leadership and fiscal support. This report clearly called for Americans to analyze the direction of our educational practices and to reform our current educational policies. The question we need to ask is, " What is efficient teaching?"

DIRECT INSTRUCTION AS A LEARNING THEORY:

Do traditional mathematics programs exemplify efficient teaching methods? Proponents of Direct Instruction would say "no". Open any basic mathematics curriculum and you will find methods that involve activities and games, however minimum attention is given to specific instruction and strategies for learning and solving mathematics concepts. For example, think about teaching the concept of equality. Texts fire problem after problem ($3+2=5$, $2+2=4$, etc.) without taking time to explain the concepts of equal and not equal. A direct instruction teacher would teach a simple definition (*"equal" means "the same as"*) to begin the conceptual development of equality.

In a direct instruction lesson a teacher would also teach a functional definition of equality. The definition is functional in that it describes a condition that must be met for the equality principle to apply (*We must end with the same number on this side and the*

other side of the equal sign). The teacher would be sure that students could define the terms: end, same, this side, other side, and equal sign.(Silbert, J., Carnine, D., Stein, M.,1990).

Silbert, J., Carnine, D., Stein, M., in the text *Direct Instruction for Mathematics*, outline the steps needed for constructing an effective efficient instructional program.

This list constitutes the basic format for a good direct instruction lesson.

1. Specify long-term and short-term objectives
2. Devise procedural strategies
3. Determine necessary preskills
4. Sequence Skills
5. Select a teaching procedure
6. Design formats
7. Select examples
8. Specify practice and review
9. Design progress monitoring procedures

Instructional sequences are the core of the Direct Instruction system. These instructional sequences are very different from traditional sequences. They are specific and sequential, building new skills on specific mastered preskills.

Mastery is a key concept in Direct Instruction theory. A student should not progress to the next subskill until a specified level of mastery has been attained. Research shows that a strong foundation of preskills is significantly more beneficial than a weak

foundation (or a foundation with preskills that have never been mastered). Although this concept seem incredibly over simplified, consider how traditional programs operate compared to Direct Instruction programs.

Because of their design, theoretically, Direct Instruction programs have a unique feature. The feature is that all the skills that will be taught will be learned by the students. Although traditional textbook analyses and evaluations of instructional programs assume this feature is true of all instructional programs, it obviously is not. If it were true of traditional basals , they would represent a paradox, because they tend to present the same material on subsequent levels of instructional programs. In math, for instance, students are taught fraction analysis in grade two or three. Some of the same work is repeated in grades four, five, and six (with an annual overlap of as much as 70% of the same material). Yet, it is not uncommon to find seventh and eighth graders who are grossly deficient in their understanding of fractions. (Adams, Gary L., & Engelmann, Siegfried1996).

Another key component of Direct Instruction is called Academic Learning Time or engaged time. This component is a recurrent issue in teacher effectiveness studies and relates directly to the concept of efficiency in education. The amount of time students are observed to be engaged actively in academic activities consistently correlates with student academic gain, both in compensatory educational settings and regular education settings (Cooley & Leinhardt, 1980, Rosenshine 1976). Students in Direct Instruction programs have a higher rate of engaged time due to small group instruction, and choral

responses which allows every child to answer every question simultaneously with the prompting of a signal.

The expectations for performance of Direct Instruction students are precise, expressed in terms of the number of lessons students are projected to master by the end of the school year. If students do not meet expectations, the Direct Instruction system assumes that the fault does not lie with the students (assuming they have an average IQ), but with the delivery system. The Direct Instruction creed is “if the student has not learned, the teacher has not taught”. (Adams, Gary L., & Engelmann, Siegfried 1996). This may sound like utopia from an educational stand point, but is it realistic, and is it effective? Project Follow Through compared nine different educational models to see which one was the most effective.

PROJECT FOLLOW THROUGH

Project Follow Through was the largest, most expensive educational experiment ever conducted. It was a federally funded program that was originally designed to be a service-oriented project similar to Head Start. However, because of funding cutbacks, the emphasis was shifted from service to program evaluation during the early years.(1968-1976). Over 10,000 low income students in 180 communities were involved in this \$500 million dollar project designed to evaluate different approaches to educating economically disadvantaged students. After 1976, Follow Through continued as a service program until its funding was eliminated in 1995. (Adams, G.L. & Engelmann, S., 1996)

The educational models included in the project varied from the highly-structured behavior analysis approach to the loosely-structured open classroom approach. To be included each model or sponsor had to have three or more active school sites that could be compared to control sites in the same community. Nine of the original sponsors qualified for inclusion in the evaluation. The models can be classified in one of three learning models. The models are affective skills models, cognitive/ conceptual skills models, or the basic skills models. The following is a list, based on theoretical orientations, of the models included in the study:

I. The Psychodynamic Approach/Affective Skills Models:

(A). Open Education Model (Education Development Center) Derived from the British Infant School model, this model focused on building the students' responsibility for their own learning. Reading and Writing were not taught directly, but by stimulating a desire to communicate.

(B)Bank Street College Model (Bank Street College of Education) This model used the traditional middle-class nursery school approach that was adopted by Head Start. This model dealt with learning centers and students have many options.

(C)Responsive Education Model (Far West Laboratory) This was an eclectic model using the work of O.K. Moore, Maria Montessori, and Martin Deutsch. This model used learning centers and the student's interests to determine when and where the student was placed for learning.

II. The Cognitive Developmental Approach/ Cognitive-Conceptual Skills Models:

(A) Cognitively-Oriented Curriculum Model (High Scope Foundation) This popular model was based on Piaget's descriptions of underlying cognitive processes. The teacher's fostered a positive self-concept through the way the students were given choices.

(B) Tuscon Early Education Model (TEEM) (University of Arizona) TEEM used a language-experience approach (much like whole language) that attempted to elaborate the student's present experience and interest. This model assumes that students have different learning styles so child-directed choices were important.

(C) Florida Parent Education Model (University of Florida) This approach taught parents of disadvantage students how to teach their children. At the same time students were taught in the classroom using a Piagetian approach. Emphasis included not only language instruction, but also affective, motor, and cognitive skill instruction

III. The Behaviorist Approach /Basic Skills Models:

(A) Behavior Analysis Model (University of Kansas) This model used a behavioral (reinforcement) approach for teaching reading arithmetic, handwriting, and spelling.

(B) Direct Instruction Model (University of Oregon) This model used the DISTAR. DISTAR stands for Direct Instruction System for Teaching And Remediation. This model assumed that the teacher is responsible for what students learn.

(C)Language Development (Bilingual)Model (Southwest and Educational Developmental Laboratory) This curriculum-based model used an eclectic approach based on language development.

The nine sponsors were categorized by theoretical orientations of models first and then by the degree of structure. This system was developed by White(1973). According to White:

High structure involves curriculum bases predetermined roles for teachers and students. These roles were developed by the project planners. Teachers were expected to directly lead the students and students were expected to follow the teacher's lead. The implementation were expected to be consistent across classrooms.

Low structure involves teachers instructing based on their own educational philosophy and experience within the project's framework. Teachers and students were free to select activities according to their needs. This process led to a wide variety of classroom implementations.

Middle structure involves mixing low and high structure activities. Teachers and students had broad guidelines for implementation. The teacher used high structure curriculum-based periods and low structure activity periods. However, the high structure activities were based on broad objectives, not step by step implementation requirements.

Abt. Associates (Stebbins, St, Pierree, Proper, Anderson, & Cerva,, 1977) categorized the nine different models in the chart shown in Table 2-1.

Abt. Associates analyzed the data by comparing each Follow Through model's scores to both the local comparison group and the national pooled comparison group. The comparison group was created by combining the comparison groups from all nine Follow Through models.

Table 2-1
Dimensions of the Nine Follow Through Models

<u>EMPHASIS ON LEARNING DOMAIN</u>			
<u>DEGREE OF STRUCTURE</u>	Basic Skills	Cognitive-Conceptualized	Affective
High	Behavior Analysis Direct Instruction		
Medium	Southwest Lab	Southwest Lab TEEM Cognitive Curriculum	Responsive Education
Low			Bank Street Open Education
Unknown		Parent Education	

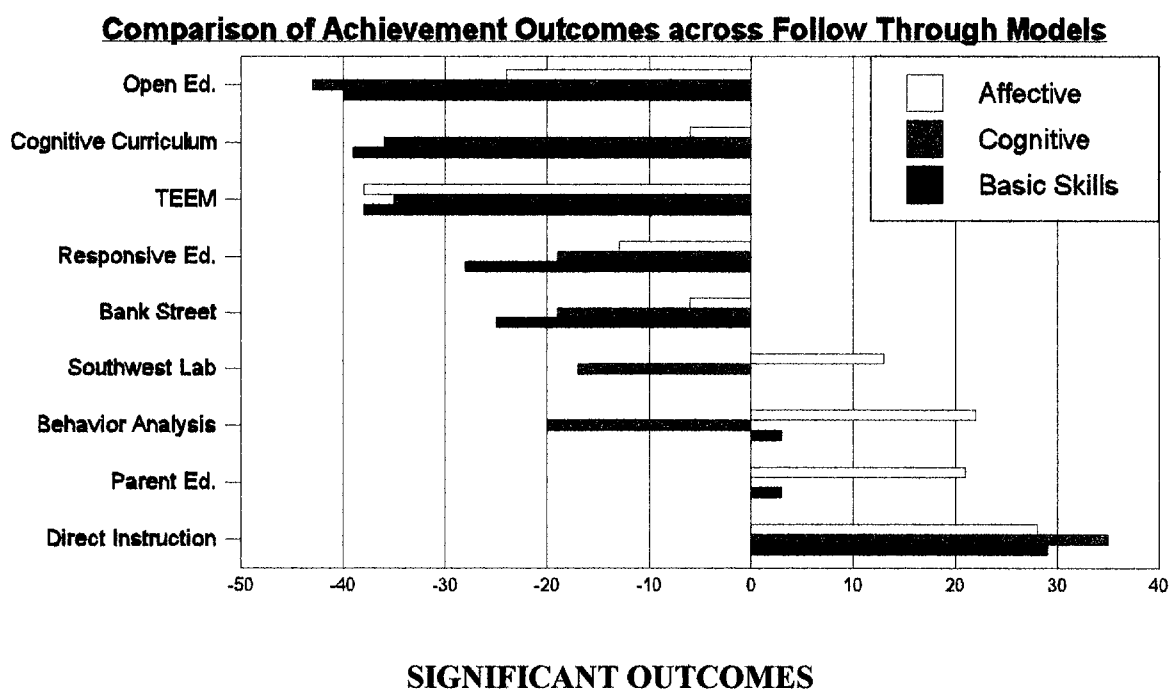
(Adams, Gary L., & Engelmann, Siegfried, 1996).

Local comparison scores and national pooled comparison scores were used as covariates to analyze each variable. A plus (+) was given if (a) the Follow Through (FT) model exceeded the Non-Follow Through (NFT) models by one-fourth standard deviation (.25 effect size) and (b) the difference was statistically significant. A minus (-) was given

if the NFT score exceeded the FT score by one-fourth standard deviation (.25 effect size) and was statistically significant. If results did not reach either the plus or the minus criterion, the difference was null and left blank. Adams, Gary L., & Engelmann, Siegfried. (1996).

Figure 2-2 shows the result of this analysis for third graders. The number of negative scores shows that the local or national pooled comparison group scores were higher than most of the Follow Through models.

Table: 2-2



** 0= No difference between the Follow Through model and the comparison group (adapted from Stebbins et al.,1977)

The Direct Instruction model was the only model that had a positive score on all three types of outcomes measured (Basic Skills, Cognitive, and Affective). Researchers expected that the results would have related more to model orientations than they did. For example, it would be expected that the three basic skill models would have the best scores in basic skills, and they did. It would also be expected that the Affective Skills models-models that specifically target improving affective behavior-would have the highest score in the affective measures. They did not!

This was a surprising outcome of the study due to the fact that the Direct Instruction model has received significant criticism about being so scripted and rigid. As the Abt Associates' authors note:

“Critics of the model have predicted that the emphasis of the model on tightly controlled instruction might discourage children from freely expressing themselves and thus inhibit the development of self-esteem and other affective skills.” (Stebbins, L.B., St. Pierre, R.G., Proper, E.C., Anderson, R.B., & Cerva, T.R. 1977, p.8.).

This study found that a highly structured, basic skills method did not diminish or retard children's affective growth. In fact, the children's self esteem grew as their skills improved. Perhaps learning is an intrinsic reward by itself. This study supports the theory that we need to teach children the basics in a systematic, programed way that encourages mastery prior to learning new material. The Direct Instruction Model, according to the largest study even funded was efficient, successful, and developed a positive self esteem in the students on which it was used.

THE NEED FOR AUTOMATICITY OF BASIC MATH FACTS:

If Direct Instruction techniques, as the research suggests, prove to be highly effective as a method for teaching skills, then it stands to reason that we should use these concepts in designing a study. One of the key concepts that this study will investigate is the concept of mastery. When dealing with math facts we are specifically discussing mastery to the point of automaticity.

Automaticity, as defined in chapter one, is the ability to recall automatically certain rote-memory facts such as math facts. Automaticity is demonstrated by the ability to recall math facts within two seconds of the visual or auditory presentation of the fact. (Bender, W.N., 1998). This, clearly, means memorized to the point where recall is completely automatic. A student who still uses his fingers, or other counting method (such as bobbing his head as he counts) has not mastered his basic math facts.

Most cognitive scientist now believe that as basic math facts are practiced more, their execution requires less cognitive processing capacity, or attention, and becomes automatic. All people have a limited capacity for information processing. If they do not have to use part of this limited capacity performing basic math facts, there is more capacity left to execute higher level skills. Thus it appears that the ability to succeed in higher level skills is directly related to the efficiency with which lower level processes are executed. (Hasselbring, T. S., Goin, L. I., Bransford, J. D., 1987)

An automatic process makes few demands on central processing capacity and can, therefore, operate in parallel with other processes. Thus, automatic processing would reduce or eliminate the degree to which (a) a second task would interfere with processing (e.g., Logan, 1979) and (b) processing load would slow processing (e.g., Fisk & Schneider, (1983). For example, take a look at the skill of subtraction with regrouping. In the subtraction problem at the right, if a student has not reached a level of automaticity, he will have to stop to compute $13-6=$ on his fingers or calculator (or with whatever other compensation method he has developed). Research tells us that a student is more likely to get confused in the regrouping process, when he stops for more than a few seconds to compute. On the other hand, if the fact $13-6$ was memorized the student would not need more than two seconds for recall and the main process-regrouping-would not get interrupted.

$\begin{array}{r} 473 \\ - 216 \\ \hline \end{array}$

THE METHODS TO ACHIEVE AUTOMATICITY:

Davis, in the 1978 Yearbook of the National council of Teachers of Mathematics, reviewed research finding and consolidated the findings into a list of ten suggestions for the best practices in teaching the memorizing math facts.

1. Children should attempt to memorize material they reasonably understand.
2. Have children begin to memorize basic arithmetic facts soon after they demonstrate an understanding of symbolic statements.

3. Children should participate in drill with the intent to memorize.
4. During drill sessions, emphasize remembering-don't explain.
5. Keep drill sessions short, and have some drill almost every day.
6. Try to memorize only a few facts in a given lesson, and constantly review previously memorized facts.
7. Express confidence in your students' ability to memorize-encourage them to try memorizing and see how fast they can be.
8. Emphasize verbal drill activities and provide feedback immediately.
9. Vary drill activities and be enthusiastic.
10. Praise students for good efforts-keep a record of their progress.

This list by Davis (1978), along with the practices discussed in the section about the theory behind direct instruction were utilized for the purpose of designing this research study. Many of the suggestions in the list above are incorporated in a direct instruction model.

AUTOMATICITY OF BASIC MATH FACTS FOR STUDENTS WITH LEARNING PROBLEMS:

Research shows that children with learning disabilities are referred for special education services most often due to difficulties in reading, however many of these students also have difficulty in mathematics. In one study teachers were questioned about why their learning disabled students were receiving services. They found out that (a)

nearly two out of three were receiving help in mathematics and (b) more than one in four had been assigned to special education primarily because of learning disabilities and mathematics. (McLeod & Armstrong, 1982)

Children with learning disabilities in the area of math experience problems in counting, writing numerals, and learning basic concepts. Very few learning disabled students are proficient or even competent in basic addition and subtraction facts. While most can compute simple answers by using some counting strategy (usually one that they have devised as an alternative strategy to memorization), few can retrieve answers to basic math facts automatically. (Russell, R. L. & Ginsburg, H. P., 1984)

In another study by Merrill, Goodwyn, and Gooding (1996), the acquisition of automatic processing in persons with mental retardation (mean IQ of 63.2) and without was studied. The results were that subjects without mental retardation needed relatively less practice than subjects with mental retardation before evidence of automaticity was observed.

Most children with mild learning disabilities have difficulty performing basic math skills, which causes a major problem in the acquisition of higher level skills and therefore overall success in math. The major reason students do poorly in math is their inability to recall basic math facts automatically. Research indicates that neither paper-and-pencil drill and practice nor computer-based drill and practice, in itself, is powerful enough to develop automaticity in mildly handicapped students. Practice that allows students to use counting strategies for problem solving only serve to strengthen their use

of counting strategies (or calculators) and does little to move them toward a state of automaticity (Hasselbring, et al 1986).

CHAPTER III

DESIGN OF THE STUDY

INTRODUCTION:

The research for this thesis was conducted at Thomas Sharp Elementary School in Collingswood, New Jersey with the express permission of the principal, Maria Heckendorn. The purpose of this study is to prove, through a systematic approach, that teaching addition facts to mastery will improve the mathematics scores of second grade students. Systematically teaching basic math fact to a group of students over several months and testing them daily on speed and accuracy should, for most students, bring them to a higher level of automaticity. We would then compare standardized test scores from the end of first grade (prior to the intervention) and end of second grade scores (after the intervention) for each child who participated in the experimental group. The test group would then be compared to a group that had no intervention to see if there was a significant level of improvement. This would also be assessed by analyzing their end of first grade and end of second grade standardized test scores.

DESCRIPTION OF SAMPLE:

The population of students selected for this study consisted of the entire group of students in second grade at Thomas Sharp Elementary School. In September, the beginning of the school year, there were two second grade classes each officially having twenty-five students on record. The group was divided, based on convenience, into two groups. The control group consisted of one entire class, and the experimental group consisted of the other entire class of second graders. The students in the sample population, for the most part, provided a fair representation of the community as a whole, in terms of racial, and economic distribution.

There were a total of fifty students at the beginning of the study. However, several students were eliminated from the study over the course of the school year. In the control group five students were eliminated from the study due to the fact that they were not in this district for first grade and no first grade California Achievement Test scores were available. Four additional students were disqualified from the control group because they left the district prior to final testing. This left a total of sixteen students in the control group. One of these sixteen students was classified as needing special education services.

The experimental group also had subjects disqualified over the course of this study. Five students in this group were new to the district at the beginning of second grade and no California Achievement Test scores were available. There were no students that transferred out of the district in the experimental group. Of the twenty remaining students

three were classified as needing special education services and two received basic skills services throughout the school year.

DESCRIPTION OF INSTRUMENTS USED:

1. California Achievement Tests (CAT) -This is a group administered, norm referenced achievement test which is administered district wide in the spring of each school year. The mathematics subtests of the California Achievement Tests are “computational” and “concept application”. The CAT also provides a “total battery” score which includes the overall ability for the entire mathematics portion of the test. This study was concerned with the “total battery” scores due to the fact that the automaticity of computational skills can have an effect on concept application .

2. Daily math facts speed drill worksheets -These sheets were designed by a student at Glassboro State College in 1980. The set consists of thirty math fact sheets for each operation (addition, subtraction, multiplication, and division). The addition and subtraction sheets were used in the experimental group’s classroom. The addition sheets start with sheet A-1 which contains problems like $1+1$, $1+2$, and $1+3$. Each sheet, in progression, adds three or four new math facts. As new facts are added the student is not only responsible for those new problems, he is also responsible for all previously taught facts. Once a student masters the final addition sheet(A-30) he moves to the subtraction fact sheets(S-1).

Each sheet contains 72 problems and students are allotted two minutes to complete as many problems as possible. Mastery is achieved when a student can accurately complete 60 problems within the two minute time period. The student is only allowed one error on the sheet. If mastery occurs the student advances to the next sheet. If mastery on a specific sheet is not attained that sheet is repeated the next day.

DESIGN OF THE STUDY:

The control group was taught math using the school's standard mathematics curriculum. The group's classroom teacher was responsible for teaching as usual and was unaware of the ongoing study.

The experimental group was also taught math using the school's standard mathematics curriculum. However, in addition to the regular daily math lessons, the students in this group were given a daily timed math fact sheet to complete. As facts were learned to the point of automaticity (based on the number completed within the two minute time period) the students moved on to the next level drill sheet. Each child moved at his own pace. Some students were able to master almost one sheet a day, while other students stayed on the same sheet for several days. The important part was that the sheet was mastered and automaticity was achieved.

This program was in place by November of the school year and continued daily (with a few exceptions) until the California Achievement Tests were administered in April of that school year. The end of year California Achievement Tests for first grade

and the end of year California Achievement Tests for second grade were compared to see if the students who received the treatment (and hopefully were more proficient with their basic facts) made larger gains or scored better than the students in the control group.

A quasi-experimental design will be used to evaluate the effects of direct instruction since this study is being conducted in a “natural social setting” where a true experiment is not feasible. (Campbell & Stanley, 1963). The specific quasi-experimental design that will be used in the evaluation is a form of “nonequivalent control group design” This design involves using pretest and posttest scores to compare the performance of a group of subjects who are exposed to an experimental treatment (i.e. experimental group) with those of a group who are not (i.e. control group). The two groups are considered “nonequivalent” because the subjects were not randomly distributed between them; therefore, the pretest scores are used as evidence of the comparability of the two groups prior to treatment.

In applying this nonequivalent control group design to the present study, students who receive traditional mathematic instruction plus intensive daily drill in math facts will be considered the experimental group. The control group will consist of only traditional mathematics instruction. The subjects of the study consists of students in grade 1 in the initial year of 1996-1997 and grade 2 in 1997-1998. Table 3-1 depicts the experimental and control group and their pre and posttest dates.

Table 3-1
Math Pretests and Posttests

	Pretest 1996-1997	Posttest 1997-1998
Experimental Group	Grade One	Grade Two
Control Group	Grade One	Grade Two

ANALYSIS OF THE DATA:

Analysis of the California Achievement Tests scores for both the control and the experimental group will be accomplished by a visual inspection by the classroom teachers. All of the students in the study were given a code number to identify them so that the student's identities remain anonymous. The teacher's reported the scores in chart form giving both the end of first grade and the end of second grade California Achievement Tests scores.

Analysis of the data obtained in this study will require two separate statistical procedures. They are (1) an independent samples t test to compare pretest scores of the experimental and control groups and (2) independent samples t test to determine if posttest scores of the experimental group statistically significantly are greater than those of the control group.

The comparability of the pretest results will be established and results of the posttest will be examined. Computations for the statistical tests will be accomplished

using the SPSS 7:5 Statistical Package located in the Psychology Department Behavioral Sciences Lab located in Robinson, rooms 121-122 at Rowan University.

An in-depth discussion of the results of the data will be reported in chapter four of this study.

CHAPTER IV

ANALYSIS OF RESULTS

INTRODUCTION:

The purpose of this study is to prove, through a systematic approach, that teaching addition facts to mastery will improve the mathematics scores of second grade students. This study will attempt to demonstrate that if a desired level of automatic recall of basic fact is achieved students will show improved scores on a nationally standardized test. Systematically teaching basic math facts to a group of students over several months and testing them daily on speed and accuracy should for most students bring them to a higher level of automaticity. We would then compare standardized test scores from the end of first grade (prior to the intervention) and end of second grade scores (after the intervention) for each child who participated in the experimental group. This group would then be compared to a group that had no intervention to see if there was a significant level of improvement, as measure by their end of first grade and end of

second grade standardized test scores. This thesis addressed one basic research question and tested two hypothesis as follows:

Research Question: Will second grade students who receive direct instruction, drill and practice of basic addition facts make greater gains on the California Achievement Tests than a control group that has had no intervention?

In order to answer the research question the following hypotheses were tested:

H₁ -There is no difference in basic calculation skills between the experimental group and the control group used in this study.

H₂ -Second grade children who receive four months of Direct Instruction in basic math facts will make greater gains in computational skills than a comparable group of second graders that do not receive the Direct Instruction method.

Analysis of the data obtained in this study required two separate statistical procedures. They were (1) an independent samples t test to compare pretest scores of the experimental and control groups and (2) independent samples t test to determine if posttest scores of the experimental group statistically significantly are greater than those of the control group.

The comparability of the pretest results will be established and results of the posttest will be examined.. Computations for the statistical tests will be accomplished using the SPSS 7:5 Statistical Package located in the Psychology Department Behavioral Sciences Lab located in Robinson, rooms 121-122 at Rowan University.

RESULTS:

The data gathered in this study has suggested an answer to the research question. The data will be presented in the form of tables. A narrative discussion of the tables will follow.

Table 4-1
CONTROL GROUP PRETEST AND POSTTEST STANDARD SCORES

<u>STUDENT #</u>	<u>PRETEST</u> <u>STANDARD SCORE</u> <u>END OF FIRST GRADE</u>	<u>POSTTEST</u> <u>STANDARD SCORE</u> <u>END OF SECOND</u>
1	115	98
2	135.5	128.5
3	108.5	131
4	135.5	122
5	122	118
6	113	107
7	122	119
8	131	135.5
9	77	110.5
10	126.5	131
11	123	135.5
12	122	135.5
13	124.5	105
14	135.5	135.5
15	105	114.5
16	135.5	114

The first table reports the results of the control group's pretest (administered at the end of their first grade year, April 1997) and posttest (administered at the end of their

second grade year, April 1998). The test used was the California Achievement Test-Mathematics Composite. The scores that are reported are standard scores. (Table 4-1)

Table 4-2
EXPERIMENTAL PRETEST AND POSTTEST STANDARD SCORES

<u>STUDENT #</u>	<u>PRETEST STANDARD SCORE END OF FIRST GRADE</u>	<u>POSTTEST STANDARD SCORE END OF SECOND</u>
1	85.5	119
2	128.5	126.5
3	109.5	115.5
4	135.5	131
5	94	114
6	135.5	131
7	121	122
8	135.5	131
9	107	114.5
10	91.5	106.5
11	110	135.5
12	135.5	131
13	121	114.5
14	126.5	135.5
15	135.5	131
16	124.5	105.5
17	118.5	101.5
18	84	109.5
19	128.5	135.5
20	108	119

The next table reports the results of the experimental group's pretest (administered at the end of their first grade year, April 1997) and posttest (administered at the end of their second grade year, April 1998). Again, the test used was the California Achievement Test-Mathematics Composite. The scores that are reported are standard scores.(Table 4-2)

Analysis of the data obtained in this study required two separate statistical procedures. They were (1) an independent samples t test to compare pretest scores of the experimental and control groups and (2) independent samples t test to determine if posttest scores of the experimental group statistically significantly are greater than those of the control group.

Table 4-3 explains the results of the independent sample t test for the pretests of both the control and experimental groups.

TABLE 4-3
INDEPENDENT SAMPLES T TEST
FOR TESTING HYPOTHESIS 1

Group	N	$\bar{x} \pm 1.96 \frac{SD}{\sqrt{n}}$	MEAN
Control Group (end of first grade)	16	134.10 - 99.46	116.78
Experimental Group (end of first grade)	20	135.85 - 105.58	120.72

* Not significantly different at the .05 level of Type I error.

The independent samples t test yielded a mean standard score for the control group of 116.78. The standard deviation for this group was ± 17.32 . This means that it is 95% likely that the scores fall within the range shown in the table. For the experimental group the independent samples t test yielded a mean standard score of 120.72 . The standard deviation for the experimental group was ± 15.14 . This means that it is 95% likely that the scores fall within the range shown on table 4-3. Statistically there is not a significant difference between the two groups pretest scores.

TABLE 4-4
INDEPENDENT SAMPLES T TEST
FOR TESTING HYPOTHESIS 2

Group	N	$\bar{x} \pm 1.96 \frac{SD}{\sqrt{n}}$	MEAN
Control Group (end of second grade)	16	133.64 - 108.92	121.28
Experimental Group (end of second grade)	20	132.45 - 110.49	121.47

* Not significantly different at the .05 level of Type I error.

The independent samples t test yielded a mean standard score for the control group of 121.28. The standard deviation for this group was ± 12.36 . This means that it is 95% likely that the scores fall within the range shown in the table 4-4. For the experimental group the independent samples t test yielded a mean standard score of 121.47 . The standard deviation for the experimental group was ± 10.98 . This means that

it is 95% likely that the scores fall within the range shown on table 4-4. Statistically there is not a significant difference between the two groups posttest scores.

Therefore, we have a statistical answer to the research question: Will second grade students who receive direct instruction, drill and practice of basic addition facts make greater gains on the California Achievement Tests than a control group that has had no intervention? The scientific answer is that there were no differences, statistically, in the pretest calculation abilities of the control or experimental groups, and there were no differences, statistically, in the posttest calculation abilities of the control or experimental groups. A discussion of these results and implications for further research will be discussed in chapter five.

CHAPTER V SUMMARY

SUMMARY:

The purpose of this study was to prove, through a systematic approach, that teaching addition facts to mastery would improve the mathematics scores of second grade students. This study attempted to demonstrate that if a desired level of automatic recall of basic fact was achieved students would show improved scores on a nationally standardized test.

Basic math facts were taught to a group of students over several months and they were tested daily on speed and accuracy . We then compared standardized test scores from the end of first grade (prior to the intervention) and end of second grade scores (after the intervention) for each child who participated in the experimental group. This group was then compared to a group that had no intervention to see if there was a significant level of improvement, as measure by their end of first grade and end of second grade standardized test scores.

The findings to the research question was that there were no differences, statistically, in the pretest calculation abilities of the control or experimental groups, and

there were no differences, statistically, in the posttest calculation abilities of the control or experimental groups. However it can not be concluded that individual students didn't make significant gains with the extensive drill and practice. Further research with a larger group of subjects may lead to more significantly favorable findings.

CONCLUSIONS:

The information obtained was analyzed, and resulted in the following findings:

(1) There was no significant difference, statistically, in basic calculation skills, prior to intervention as measured by the pretest, between the experimental group and the control group used in this study.

(2) Second grade children (experimental group) who receive four months of Direct Instruction in basic math facts did not make statistically greater gains in computational skills, as measured by the posttest, than a comparable group of second graders (control group) who did not receive the Direct Instruction method.

DISCUSSIONS AND IMPLICATIONS:

Further discussions of these result may help to clarify some of the findings. One major point of discussion that should be addressed is the research on significant results with small sample sizes. A researcher named Bruce Thompson has written an article pertaining to the research on improving research clarity and usefulness. His research demonstrated that studies involving a small number of subjects rarely produce

significant results. This is due to the large standard deviation presents with small samples. As the number of subject increases the standard deviation decreases thus narrowing the range of scores and allowing a lesser chance of overlapping scores when comparing two ranges, as was done in this study. (Thompson, B. ,1999)

Had this been a research study with 1000 or more subjects with the same data (times them by 50 for the experimental group to get 1000 sets of scores) would these result have been more significant? Thompson's research indicates that there is a strong possibility the results could have been significant.

Although the findings of this study do not appear to be scientifically significant some positive conclusions can be made. In tables 5-1 & 5-2 (modifications of tables 4-1, & 4-2) students were analyzed for gains in their standard score over the one year period. The experimental group had five students out of 20 whose standard scores improved by more than 15 points from the pretest to the posttest. This equates to 25% of the students that exhibited a gain of 15 points or more. When the data for the control group is analyzed in the same way only one student out of 16 scored 15 points or more higher (using their standard score) than on the posttest. This equates to only 6.25% of the students in the control group that demonstrated this much gain. Student #5 gained 20 points and students number 1, 11, and 18 gained over 25 standard points during this study! Clearly individual students made significant gains with the prescribed interventions. In the control group only student number nine demonstrated a gain of more

than 15 points when comparing both the pretest and posttest scores. See tables 5-1 and 5-2.

Table 5-1
EXPERIMENTAL PRETEST AND POSTTEST STANDARD SCORES
POINTS GAINED

<u>STUDENT #</u>	<u>PRETEST STANDARD SCORE END OF FIRST GRADE</u>	<u>POSTTEST STANDARD SCORE END OF SECOND</u>	<u>POINTS GAINED OVER ONE YEAR</u>
1	85.5	119	+33.5
5	94	114	+20
10	91.5	106.5	+15
11	110	135.5	+25.5
18	84	109.5	+25.5

TABLE 5-2
CONTROL GROUP PRETEST AND POSTTEST STANDARD SCORES
POINTS GAINED

<u>STUDENT #</u>	<u>PRETEST STANDARD SCORE END OF FIRST GRADE</u>	<u>POSTTEST STANDARD SCORE END OF SECOND</u>	<u>POINTS GAINED OVER ONE YEAR</u>
9	77	110.5	+33.5

One implications of these findings is that if we are able to help 25% of the students in one class make significant improvement in their ability to do mathematical calculations then maybe we should implement a program like this. Since this program only takes about five minutes a day to implement it makes sense to add it to existing mathematic curricula.

We can also look at students who lost points over the one year period. The experimental group had two out of 20 students who lost more than ten standard score points. That is equivalent to 10% of the experimental group that tested lower in the second year of the study . On the other hand, the control group had four out of 16 students who demonstrated a standard score 10 points or more lower than the previous year's score. This equates to 25% of the students in the control group scoring ten or more points lower in the posttest.

Table 5-3
EXPERIMENTAL PRETEST AND POSTTEST STANDARD SCORES
POINTS LOST

<u>STUDENT#</u>	<u>PRETEST STANDARD SCORE END OF FIRST GRADE</u>	<u>POSTTEST STANDARD SCORE END OF SECOND</u>	<u>POINTS LOST OVER ONE YEAR</u>
16	124.5	105.5	-19
17	118.5	101.5	-17

TABLE 5-2
CONTROL GROUP PRETEST AND POSTTEST STANDARD SCORES
POINTS LOST

<u>STUDENT #</u>	<u>PRETEST STANDARD SCORE END OF FIRST GRADE</u>	<u>POSTTEST STANDARD SCORE END OF SECOND</u>	<u>POINTS LOST OVER ONE YEAR</u>
1	115	98	-17
4	135.5	122	-13.5
13	124.5	105	-19.5
16	135.5	114	-21.5

RECOMMENDATIONS FOR FURTHER RESEARCH:

This is an important study and to discount the results due to them not being significant would be a mistake. This project clearly indicates that individual children most definitely benefitted from the intervention provided during this project. The question remains that if the sample had been larger would the results have been more significant? Researchers have proven that sample size is directly related to the probability of getting scientifically significant results (Thompson, B. ,1999) Therefore, it may be beneficial to conduct another study with a sample size of 100 or more students in each of the two groups (the experimental and control). The larger sample size should, in theory, produce results with significant results.

Another question which could be addressed as a result of this study is “How do the students who receive intervention in math fact memorization do over a long period of time?” If a longitudinal study could be done with these same two classes we could look at the fourth grade, eighth grade and High School Proficiency bench mark scores to see how these students progress over their entire school life.

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